A Micro-Electro-Mechanical System (MEMS) for the Measurement of Density and Viscosity

A.R.H. Goodwin [C, S]
Schlumberger Cambridge Research, Cambridge, United Kingdom

E.P. Donzier
Schlumberger-Doll Research, Ridgefield, CT, U.S.A.

M. Manrique de Lara
Schlumberger Cambridge Research, Cambridge, United Kingdom

O. Vancauwenberghe
Schlumberger-Doll Research, Ridgefield, CT, U.S.A.

Measurements of the density and viscosity of fluids are required by Industry to design chemical process equipment and control production processes. In the petroleum industry, measurements of density and viscosity are required to determine the value of the produced fluid and production strategy. In this work, a Micro Electrical Mechanical System (MEMS) has been developed to determine both density and viscosity of fluids. This device is based on a vibrating plate, with dimensions on the order of 1 mm and a mass of about 0.3 mg, clamped along one edge. The resonance frequency, under vacuum, of the first bending mode is about 12 kHz, at a temperature of 298 K, with a quality factor of about 2900. Measurements of the resonance frequency and quality factor of the vibrating plate were combined with mechanical properties of the plate to determine, with a hydrodynamic working equation, the density and viscosity of the fluid surrounding it at temperature and pressure. Densities, in the range (1 to 1300) $kg.m^{-3}$, and viscosities, in the range (10 to 50000) μPa s, were determined with the vibrating plate for argon, methane, nitrogen, a natural gas, octane, toluene, a polydimethylsiloxane, a reservoir oil, and brine. These measurements, when compared with either accepted literature values or results obtained with experimental techniques that utilise different principles, and thus have quite different sources of systematic error, were found to lie within ±1 per cent for density and ±5 per cent for viscosity of the literature values.